comprising at least a step for measuring a surface profile, using a point diffraction interferometer according to claim 7.--

--17. A manufacturing method for a reflecting mirror in which a multilayer film obtained by alternately laminating a heavy element layer and a light element layer on a substrate is formed,

comprising at least a step for measuring a surface profile, using a point diffraction interferometer according to claim 8.--

REMARKS

Claims 1-17 are pending. Claims 1-4 and 6-9 are amended and claims 11-17 are added. Prompt and favorable consideration on the merits is respectfully requested.

The attached Appendix includes marked-up copies of each rewritten paragraph (37 C.F.R. 1.121(b)(iii)) and claim (37 C.F.R. 1.121(c)(ii)).

Respectfully submitted,

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JAO:TJP/zmc
Attached: APPENDIX
Date: May 14, 2001

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APPENDIX

Changes to Specification:

The following are marked-up versions of the amended paragraphs:

Page 1, line 5 to line 7:

The present invention relates to a point diffraction interferometer used for high precision measurement of a surface profile ~~irregularity~~, a manufacturing method for a reflecting mirror, and a projection exposure apparatus.

Page 1, line 14 to line 18:

The integrated wave front aberration of the optical system used for X-ray lithography should be λ/14 rms or less, and hence precision as high as 0.2 nmrms is required for the surface profile ~~irregularity~~ (machining precision) of each mirror. For machining with such a high precision, higher precision, for example, measurement precision as high as about 0.1 nmrms is required for surface profile~~shape~~ measurement of the reflecting mirror.

Page 2, line 13 to line 17:

The collected measurement wave front (W2') is again reflected by the pinhole mirror 2 (W2"), and interferes with the reference wave front (W1) to thereby form an interference fringe on the CCD 4. A piezo device is provided on a holder (not shown) on the CCD 4, which slightly vibrates a test object to detect a change in the interference fringe with the CCD, and the surface profile ~~irregularity~~ is calculated by analyzing this change.

Page 5, line 7 to line 12:

In view of the above problems, it is an object of the present invention to provide a point diffraction interferometer which can measure the surface profile ~~irregularity~~ of a test object having a large NA with high precision (capable of measuring a profile irregularity of about 0.2 nmrms). Moreover, it is another object of the present invention to provide a manufacturing method for a reflecting mirror and a projection exposure apparatus comprising

a reflecting mirror manufactured by this manufacturing method.

Page 5, line 14 to line 21:

The present invention relates to a point diffraction interferometer which measures a surface profile ~~irregularity~~ on a surface to be measured by, irradiating light irradiated from a light source to a pinhole mirror via a collective optical system, irradiating a part of the light diffracted from a pinhole provided in the pinhole mirror to the surface to be measured as a luminous flux for measurement, making the luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of light diffracted from the pinhole, and detecting the state of an interference fringe caused by the interference.

Page 7, line 20 to page 8 line 3:

The present invention is also characterized by a point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating polarized light irradiated from a light source to a polarization retention fiber, irradiating a part of the polarized light emitted from this fiber to the surface to be measured as a luminous flux for measurement, making the luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of polarized light emitted from the fiber, and detecting the state of an interference fringe caused by the interference, wherein a $\lambda/2$ plate comprising a rotatable mechanism is arranged between the light source and the polarization retention fiber.

Page 8, line 9 to line 17:

The present invention is also characterized by a point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a single-mode fiber, irradiating a part of the light emitted from this fiber to the surface to be measured as a luminous flux for measurement, making the

luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of polarized light emitted from the fiber, and detecting the state of an interference fringe caused by the interference, wherein a dielectric multilayer reflection coating is formed on an end face on the surface side to be measured of the single-mode fiber.

Page 8, line 21 to line 25:

The present invention is also characterized by a manufacturing method for a reflecting mirror in which a multilayer film obtained by alternately laminating a heavy element layer and a light element layer on a substrate is formed, which comprises at least a step for measuring the surface profile ~~irregularity~~, using either of the above described point diffraction interferometers.

Page 11, line 6 to line 10:

On the other hand, it is known that when the pinhole diameter becomes 1/2 or less of the laser wavelength, the light quantity abruptly decreases. When the light quantity decreases, CCD noise increases, and hence an S/N ratio for sufficiently detecting the surface profile ~~irregularity~~ of the test object cannot be obtained. As a result, high precision measurement becomes impossible.

Page 17, line 20 to page 18, line 7:

A case where a surface profile ~~irregularity~~ of a reflecting mirror for EUVL is measured using the PDI of the present invention will now be described. The reflecting mirror for EUVL has a multilayer film obtained by alternately laminating a heavy element layer and a light element layer on a substrate. As the substrate, there can be used a substrate of glass, fused quartz, silicon monocrystal, silicon carbide or the like, with the substrate surface polished so as to become sufficiently smooth, compared to the used wavelength. Moreover, as the heavy element layer, there can be used a thin film of, for example, scandium (Sc),

titanium (Ti), vanadium (V), chromium (Cr), iron (Fe), nickel (Ni), cobalt (Co), zirconium (Zr), niobium (Nb), molybdenum (Mo), technetium (Tc), ruthenium (Ru), rhodium (Rh), hafnium (Hf), tantalum (Ta), tungsten (W), rhenium (Re), osmium (Os), iridium (Ir), platinum (Pt), copper (Cu), palladium (Pd), silver (Ag) or gold (Au). As the light element layer, there can be used a thin film of, for example, silicon (Si), carbon (C), beryllium (Be), silicon nitride (Si_3N_4), or boron nitride (BN).

Page 18, line 13 to line 16:

Reflecting mirrors which do not achieve the predetermined surface profile ~~irregularity~~ are machined again, and after a multilayer film has been formed, measurement of surface profile ~~irregularity~~ is performed. Until the predetermined surface profile ~~irregularity~~ is achieved, this step is repeated to manufacture the reflecting mirror.

Changes to Claims:

Claims 11-17 are added.

The following are marked-up versions of the amended claims:

1. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a pinhole mirror via a collective optical system, irradiating a part of the light diffracted from a pinhole provided in the pinhole mirror to said surface to be measured as a luminous flux for measurement, making said luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of light diffracted from said pinhole, and detecting the state of an interference fringe caused by the interference, wherein

a diameter range of said pinhole is:

$\lambda/2 \leq \phi\ PH \leq \lambda/NA$,

wherein λ is a wavelength of light irradiated from said light source, NA is a numerical aperture of said collective optical system, and ϕ PH is a diameter of said pinhole.

2. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a pinhole mirror via a collective optical system, irradiating a part of the light diffracted from a pinhole provided in the pinhole mirror to said surface to be measured as a luminous flux for measurement, making said luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of light diffracted from said pinhole, and detecting the state of an interference fringe caused by the interference, wherein

a range of a numerical aperture of said collective optical system is:

$NA \leq \lambda/\phi\ PH$,

$0 < NA < 1$,

wherein λ is a wavelength of light irradiated from said light source, NA is a numerical aperture of said collective optical system, and ϕ PH is a diameter of said pinhole.

3. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a pinhole mirror via a collective optical system, irradiating a part of the light diffracted from a pinhole provided in the pinhole mirror to said surface to be measured as a luminous flux for measurement, making said luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of light diffracted from said pinhole, and detecting the state of an interference fringe caused by the interference, wherein the light irradiated onto said pinhole is elliptically polarized light, and

$0.5 < \varepsilon < 2$,

wherein ε is ellipticity (ratio of a minor axis to a major axis).

4. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a pinhole mirror via a collective optical system, irradiating a part of the light diffracted from a pinhole provided in the pinhole mirror to said surface to be measured as a luminous flux for measurement, making said luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of light diffracted from said pinhole, and detecting the state of an interference fringe caused by the interference, wherein

said pinhole mirror has a transparent substrate, a first reflection coating and a second reflection coating comprising said pinhole, formed sequentially on this substrate.

6. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a pinhole mirror via a collective optical system, irradiating a part of the light diffracted from a pinhole provided in the pinhole mirror to said surface to be measured as a luminous flux for measurement, making said luminous flux for measurement reflected by the surface to be measured interfere with a reference luminous flux which is an other part of light diffracted from said pinhole, and detecting the state of an interference fringe caused by the interference, wherein

a dielectric multilayer reflection coating is formed on said surface side to be measured of said pinhole mirror.

7. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating polarized light irradiated from a light source to a polarization retention fiber, irradiating a part of the polarized light emitted from this fiber to said surface to be measured as a luminous flux for measurement, making said

luminous flux for measurement reflected by said surface to be measured interfere with a reference luminous flux which is an other part of polarized light emitted from said fiber, and detecting the state of an interference fringe caused by the interference, wherein

a $\lambda/2$ plate comprising a rotation mechanism is arranged between said light source and the polarization retention fiber.

8. (Amended) A point diffraction interferometer which measures a surface profile ~~irregularity~~ of a surface to be measured by, irradiating light irradiated from a light source to a single-mode fiber, irradiating a part of the light emitted from this fiber to the surface to be measured as a luminous flux for measurement, making said luminous flux for measurement reflected by said surface to be measured interfere with a reference luminous flux which is an other part of polarized light emitted from said fiber, and detecting the state of an interference fringe caused by the interference, wherein

a dielectric multilayer reflection coating is formed on an end face on said surface side to be measured of said single-mode fiber.

9. (Amended) A manufacturing method for a reflecting mirror in which a multilayer film obtained by alternately laminating a heavy element layer and a light element layer on a substrate is formed,

comprising at least a step for measuring a surface profile ~~irregularity~~, using a point diffraction interferometer according to ~~any one of~~ claim 1 ~~through claim 8~~.